A Jet Model of the Galactic Center Nonthermal Radio Filaments

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Abstract. Protostellar sources in star forming regions are responsible for driving jets with flow velocities ranging between 300 and 400 km s^{-1}. This class of jets consists of highly collimated outflows which include thermal knots with number densities estimated to be greater than that of their ambient medium. On the other hand, extragalactic FR I jets consist of light fluid with low Mach number burrowing through a denser medium as the magnetized jets radiate nonthermal emission. Both protostellar and extragalactic jets are believed to be launched by accretion disks. Here we consider a jet model in which the characteristics common to both protostellar and extragalactic jets are used to explain the origin of nonthermal filaments in the Galactic center region. We argue that these filaments are analogous to FR I extragalactic sources but are launched by embedded young stars or clusters of stars in star-forming regions.

1. Introduction

It has been 20 years since the discovery of the nonthermal radio filaments (NRFs) associated with the Galactic center Arc was first reported (Yusef-Zadeh, Morris, & Chance 1984). These observations showed evidence of linear, magnetized features running perpendicular to the Galactic plane. A number of NRFs with similar characteristics to the prototype NRFs have been discovered in the intervening years (Yusef-Zadeh 2003 and references therein). Several models have suggested that the filaments trace the illuminated component of a large-scale poloidal magnetic field pervasive throughout the Galactic center region. However, the presence of a number of filaments oriented at large angles to the normal to the Galactic plane does not support the above interpretation and indicates a different origin. Unlike most models that predict a global, static geometry of the magnetic field around the Galactic center, the model described here argues for a local origin. In the proposed picture, the NRFs originate in star-forming regions. The filaments behave like jets extracting mass and energy from embedded young stars or clusters of stars as the jets propagate in a dense ISM of the Galactic center region. A more detailed account of this model will be given elsewhere.

2. The Jet Hypothesis

Recent observations of a number of radio filaments found in the Galactic center region show a wide range of morphological structures (Nord et al. 2003; Yusef-Zadeh, Hewitt, & Cotton 2004). The new images show structures that suggest NRFs are interacting with their surrounding medium as described here briefly: (i) The distortion of the filaments from a straight geometry; (ii) subfilamentation at the point where the filaments are most distorted; (iii) an increase in the surface brightness in the middle of the filaments; (iv) a gentle curvature and a widening of the filaments; (v) gaps along the length of the filaments.

The interaction hypothesis implies the flow of high velocity nonthermal material along the filaments. This interpretation is in contrast to earlier models in which the strong preexisting organized magnetic field lines are illuminated by relativistic particles propagating at the Alfvén speed. Many of the morphological characteristics described above have also been observed in FR I sources. The presumably supersonic and super-Alfvénic jets of FR I sources are known to propagate and interact with a denser material of their ambient medium (Ferrari 1998). For example, the decollimation of some of the filaments and their gentle curvature are analogous to the morphology of bent jets, which has been interpreted in terms of collisions with clouds. The widening of one of the isolated NRFs is shown in Figure 1 [right panel] as the filament N2 runs almost perpendicular to the Galactic plane; this widening could be explained either by the negative pressure gradient expected in the direction away from the Galactic plane or by entrainment of ambient material into the jet. Another example is the lack of bright shocked emission from a hot spot at the terminus of the filament; this can be interpreted in terms of the deceleration of light jets by the surrounding medium, in similar fashion to FR I sources. Yet another example is the brightness of many NRFs peaking in the middle of the filaments. In the context of the jet model, the location of the enhanced surface brightness is where the jet changes its course as a result of an encounter with an obstacle; this in turn may lead to shocks, particle acceleration, and a change in the spectral and magnetic properties (Clarke, Burns, & Feigelson 1986). Lastly, the bundles of filaments that make up the Arc and Sgr C are examples in which the filaments broaden and appear more diffuse with a steeper spectral index in the direction away from the Galactic plane (Tsuboi et al. 1986). In analogy with FR I jets, we believe that these so-called lobes (see Fig. 1, left panel) are produced when jets with a low internal-to-ambient density ratio get decelerated and disrupted as they propagate away from the Galactic plane (see Fig. 9a of Ferrari 1998).

References

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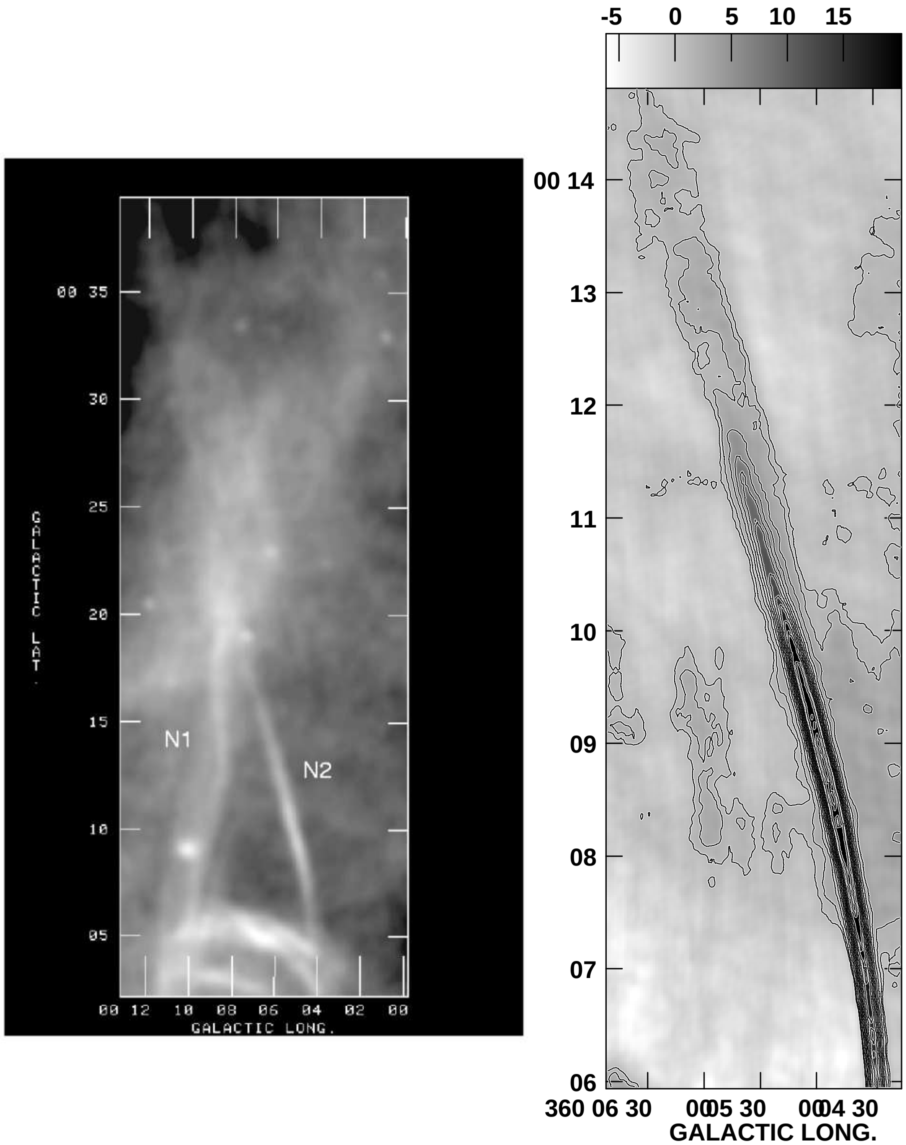

Figure 1. A 20cm continuum image of the northern extension of the Galactic center Arc [left panel] and a close-up grayscale view of N2 filament with the corresponding contours [right panel] (Yusef-Zadeh, Hewitt and Cotton 2004).